

EVAPORATION AND FOREST FIRES.

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SYNOPSIS.

Hitherto, apparently, little attempt has been made by foresters and meteorologists to correlate the factors of climate and forest fires. The purpose of this paper is to show that the occurrence and spread of large forest fires are coincident with a greatly increased rate of evaporation or a decrease in vapor pressure.

Since evaporation is a climatic complex dependent on the three major factors of temperature, humidity, and wind, the influence of any one of these may be offset by a pronounced change in either or both of the other two.

The close relation between periods of high evaporation and forest fires is strikingly brought out in figures 1 and 2. These figures also show that the rate of evaporation does not follow constantly either temperature, humidity, or wind. In some cases it follows wind alone, in others temperature, while in still others it follows changes in relative humidity only.

In southern California the wind direction is highly important. For example, an east wind blowing directly off the great deserts, brings excessively dry, hot air, resulting in extraordinary dryness in a short time.

In examining the vapor pressure data for the period 1911-1920, it was found that in those years and months when the average vapor pressure remained high a very small number of fires occurred, while in those years and months with a relatively low average vapor pressure there were uniformly periods of extreme hazard, and many bad fires occurred.—H. L.

Up to the present time there has been very little attempt on the part of foresters¹ and meteorologists² generally to correlate the different factors of climate and forest fires. Many foresters³ are now devoting considerable time to a study of fire, its behavior, and the fundamental principles underlying its severity, its rate of spread, and its climatic relationship.

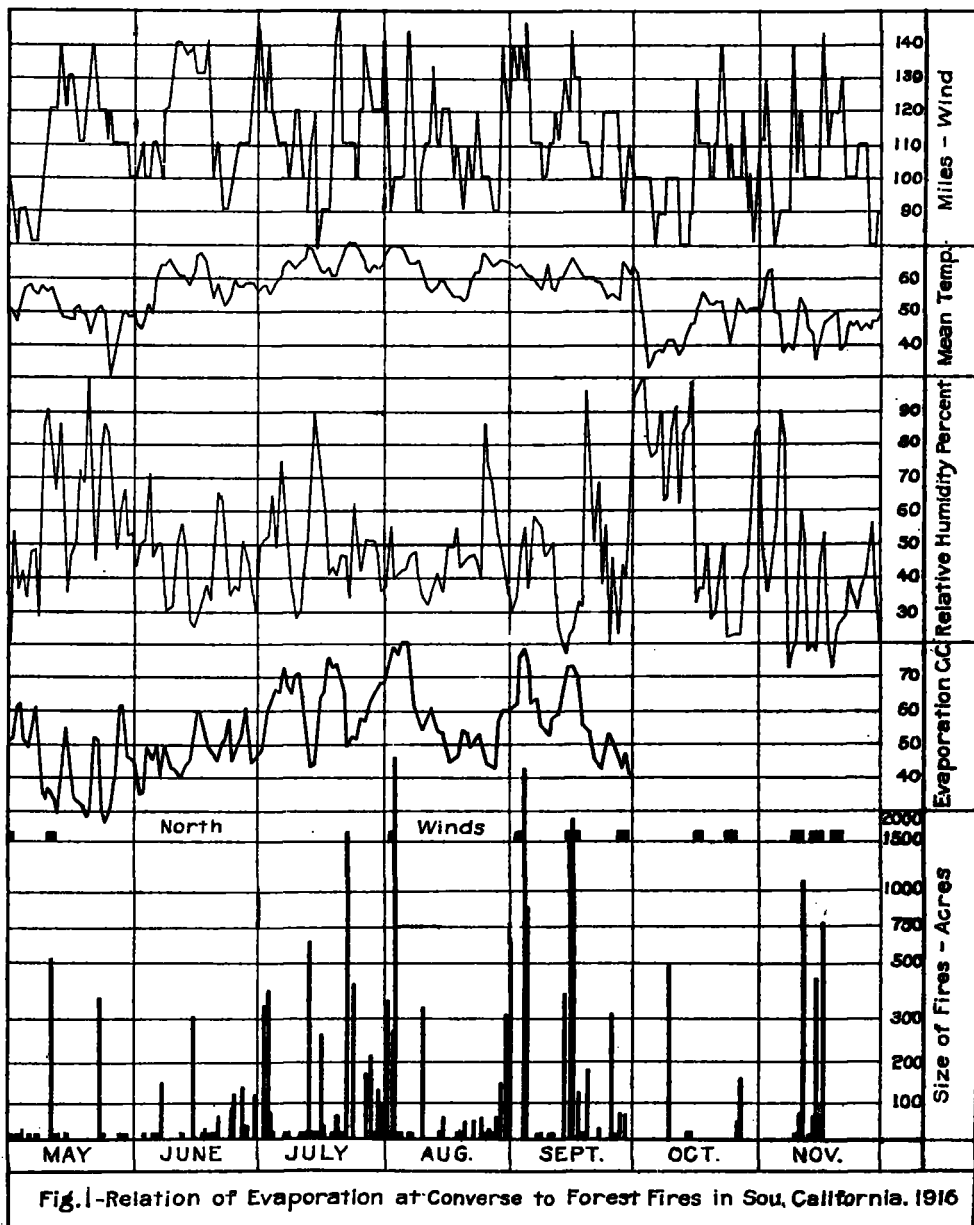
The causes which lead to the occurrence and rapid spread of large fires are not definitely known, but it has long been suspected that they are intimately related to meteorological conditions. The field force recognizes this, and in speaking of a fire, usually makes some such statement as "conditions were right for the fire to spread rapidly," or "it was an easy matter to control the fire because conditions were just right." What these "conditions" were has been largely a matter of conjecture. It is the purpose of the present paper to show how the occurrence and the spread of large fires are coincident with a greatly increased rate of evaporation or decrease in the vapor pressure.

In the present study the data here given for evaporation were obtained at Converse experiment station in the San Bernardino Mountains. This station was located in the Angeles National Forest at an elevation of 6,000 feet, about 100 miles from the ocean, and in the transition zone between chaparral and a stunted Jeffrey pine forest. Evaporation data were se-

cured from standardized porous cup atmometers exposed to the sun and wind at a height of 15 inches above the surface of the ground, in a location where a minimum of influence would be exerted by surrounding objects. The data given for any 24 hours end at 5 p. m. The amount of evaporation is expressed in cubic centimeters.

Evaporation is a climatic complex dependent on the three major factors of temperature, humidity, and wind. The influence of any one of these factors may be offset by a suitable change in either or both of the other two. How great an influence each may exert we do not know, but for general purposes they may be considered as being of equal weight. The evaporation rate may change with fluctuations in any one of the factors, following temperature, wind, or humidity.

How closely forest fires follow periods of high evaporation is shown in figures 1 and 2, where the data on daily evaporation are plotted with the size and occurrence of fires on three southern California forests. It is



¹ Plummer, Fred Gordon: Lightning in relation to forest fires. U. S. Dept. Agr. Forest Service Bulletin 111, p. 39. 1912.

² Palmer, Andrew H.: Lightning and forest fires in California. U. S. Dept. Agr. MON. WEA. REV. March, 1917. 99-102.

³ Shaw, S. B.: Climate and forest fires in northern California. Journal Forestry 17; No. 8, 985-980. December, 1919.

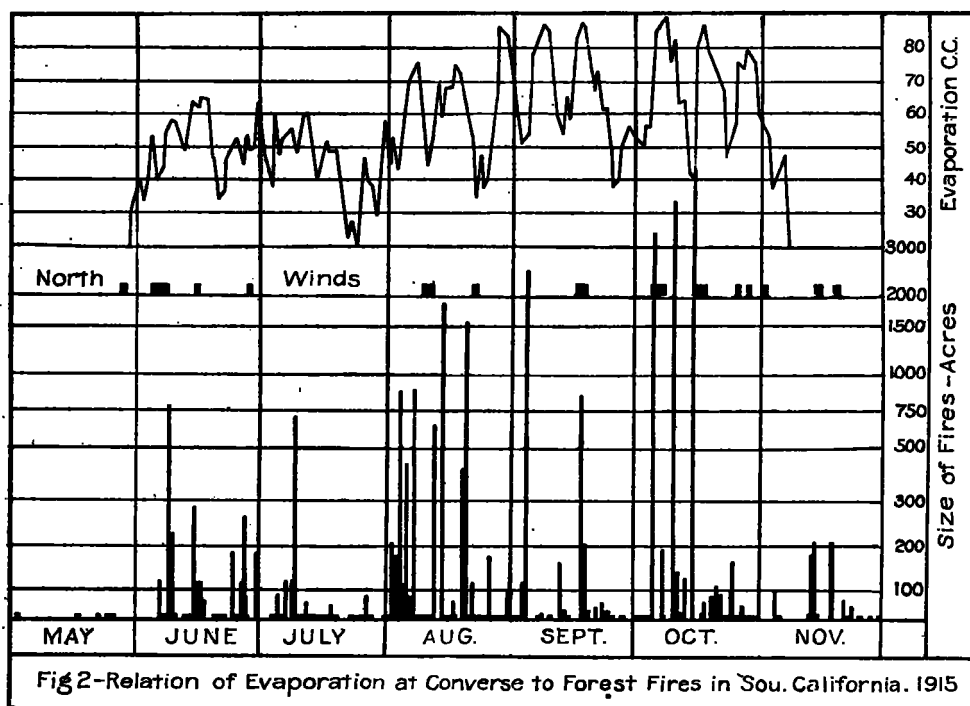


Fig 2-Relation of Evaporation at Converse to Forest Fires in Sou. California, 1915

to be noted that with an increase in the rate of evaporation the number of large fires increases, while the size of the individual fire is greatly augmented. During an extended period of low evaporation the fires are caught by the suppression forces while still small, the number starting remaining relatively a constant. With extended periods of high evaporation the number of fires starting rises and the size of the average fire greatly increases, because the rate of spread is more rapid and the possibility of early control is lessened.

It is further to be noted from these figures that the larger fires apparently occur when the evaporation is increasing. In fact, when the rate decreases the area covered is decidedly less, as would be apparent if the areas covered were plotted for the individual days during which the fire was spreading, rather than the total area plotted for the day on which the fire started, as was done here. The very largest fires, and those which have proved to be most difficult to control, have occurred during periods of high evaporation. The following examples from the Santa Barbara Forest illustrate this:

On August 19 there was a fire of 1,500 acres not controlled until the following night; the area burned was covered in two days but plotted on one. A fire of 2,500 acres is plotted on September 3 which was not controlled until the night of the fifth after burning three days. On October 4 is plotted a fire of 3,200 acres which was controlled after burning four days.

These figures also show that the rate of evaporation does not follow constantly either temperature, wind, or humidity. In some cases it follows wind alone, in others it follows temperature, while in still others it appears to follow relative humidity. Attention is also invited to the fact that the periods during which the north and east winds occurred were those in which the largest fires and those most difficult to control occurred. These north and east winds are essentially "desert" winds, and are caused by strong barometric differences. These winds coming from the great deserts are excessively dry, and no matter how wet the previous period has been rapid evaporation results and any fires occurring spread rapidly. In fact, in southern California it may be truly

said that the fire season runs from January to December, as fires occur during periods of northwinds throughout the entire winter season.

The writer has compiled and correlated the data on fire with wind direction for the period from 1913 to 1916, inclusive, for the three southern California national forests. In this connection it was noted that of 67 fires of over 500 acres, 50 occurred on days with north winds and but 20 on days with west winds. Of 42 fires of 1,000 acres or more, but three occurred with west, or ocean winds, while 39 occurred with north winds.

It has been shown that size and occurrence of fires follows the evaporation data very closely. This is a striking fact when it is considered that large parts of these three southern forests are influenced by marine conditions due to their proximity to the Pacific Ocean while other portions are under the direct influence of the Mohave Desert. It is also remarkable that an increase in the

evaporation rate taken in this high mountain country should so closely follow the occurrence of fires both on areas adjacent to the desert and those fronting on the coastal slopes. It would therefore appear that there is some major underlying factor which applies equally well to all parts of southern California, and that while the actual amount of evaporation may not be the same, the relative position of high and low rates remains constant.

After plotting the data for southern California, the fire data prepared by Mr. S. B. Shaw for the Sierra Forests were taken, to see how far this general influence extended. The result was the same as for southern California. The large fires throughout the State, from the Klamath in the northwest and the Modoc in the lava region of the northeast, to the Sequoia in the south, occurred uniformly for two years during the same periods of high evaporation rate as in southern California, while the small fires were universally concentrated on the periods of low evaporation rate. In other words, as far as California was concerned, regional location had nothing to do with the spread of the fires when the evaporation changed from a low to a high rate, and all California comes under one major meteorological province. It is difficult to believe or understand that conditions can exist which make such a definite correlation possible between evaporation and the spread and occurrence of large fires, but the data admit of no other interpretation.

As our data on evaporation cover only the two years of 1915 and 1916, it was natural to turn to the Weather Bureau to determine whether any of the data they collect would permit of a correlation between evaporation and other meteorological factors. After considerable time spent in fruitless search it was found that the data on vapor pressure gave the desired result and that the reverse of the vapor pressure curve was essentially of the same form as the curve of evaporation. Unfortunately, it has not been possible to make a direct correlation in southern California between evaporation and vapor pressure, as Los Angeles, the only station at which these data are secured, has a climate influenced to a large extent by the proximity of the ocean. However, a comparison was made with data collected at Fresno and

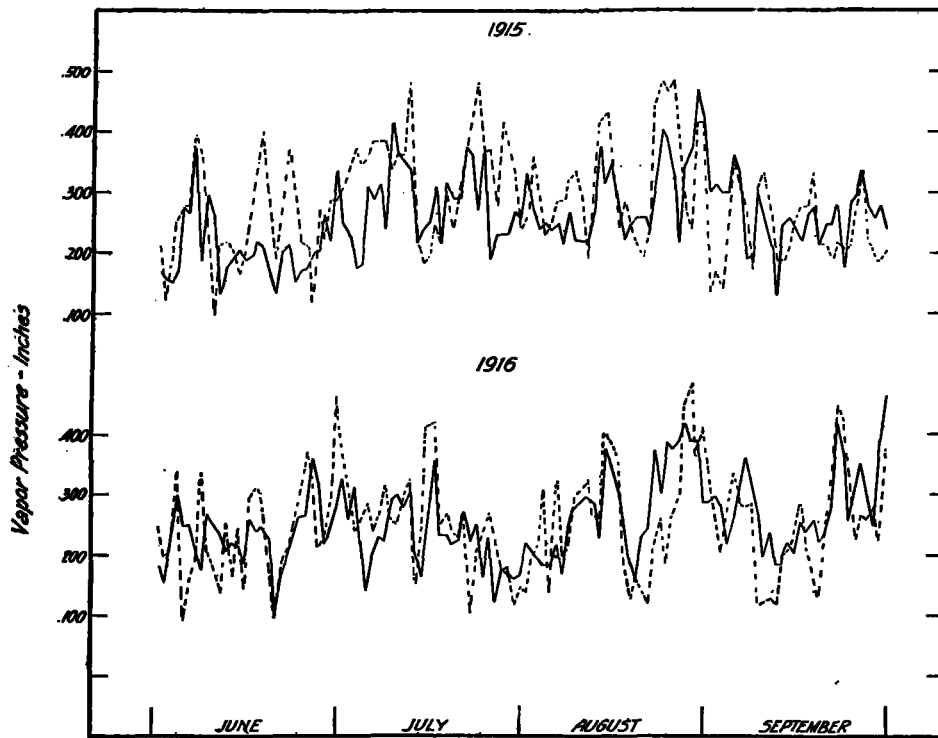


Fig. 3 - Comparison of Vapor Pressure at Fresno & Red Bluff for Fire Seasons of 1915 & 1916.

at Red Bluff, which are valley points and have a land type of climate (fig. 3). While the points do not coincide in every individual case, there is enough correlation to make certain that vapor pressure is a big factor influencing evaporation, and therefore the spread of fires, for which data are available. This is very clearly shown in figure 4, which gives the relation of vapor pressure to two large fires which occurred during 1920.

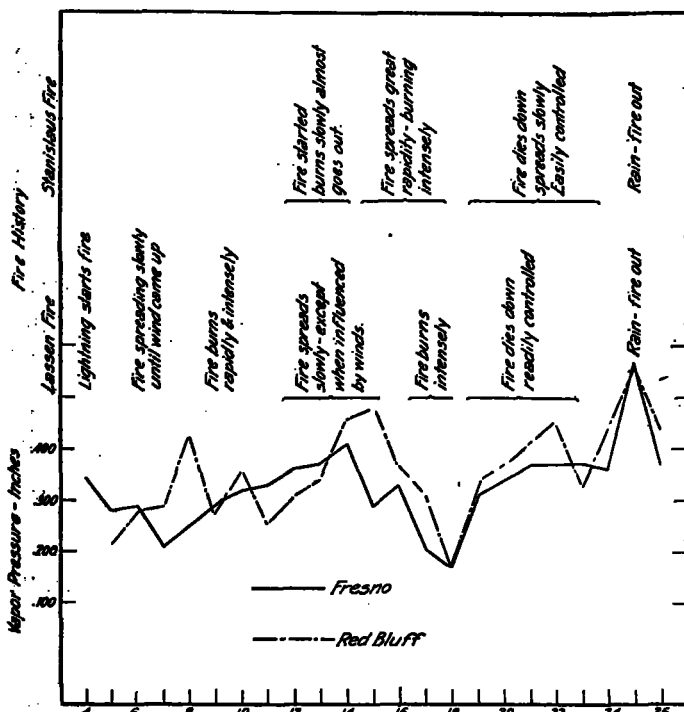


Fig. 4. Relation of Large August 1920 Fires to Vapor Pressure Conditions

On August 4 a lightning storm occurred on the Lassen Forest which was responsible for the setting of a large

number of fires.⁴ A few of these burned for several days unchecked. The men on the fire line engaged in fighting the fire noted that on some days the fire was difficult to control and burned intensely, while on other days it burned more slowly and could be closely approached. It is found that the days on which the fire spread very rapidly were those on which the vapor pressure was low, while those on which the fire spread but slowly and could be approached the vapor pressure was considerably higher, though the occurrence of wind upsets the absolute correlation.

On the Stanislaus Forest a fire started on August 12, in a narrow river canyon. For three days it was believed it would burn itself out with no damage, but on the fourth day the fire came up out of the canyon and spread rapidly in all directions. On the 18th the fire was burning most intensely and spreading most rapidly. On the 21st the fire died down somewhat and considerable work was done, and on the 22d it was practically out.

On the 23d, however, a small flare-up occurred which necessitated additional work on the fire line. A rain extinguished the fire on the 24th.

In both of the two instances cited, whenever the vapor pressure was high the fire did not burn with anywhere near the intensity that it did during the days on which the vapor pressure was decidedly low. It thus appears that the spread of fire was influenced to a very large degree by the actual amount of moisture in the air; with a large amount of moisture the fire burned slowly and much work was possible on the fire line; with a small amount of moisture in the air the fire burned intensely, making it difficult to get within striking distance of the flames to do effective work at close quarters.

It is noteworthy that the occurrence of fires and the rate of evaporation do not follow the course of relative humidity. Relative humidity is such a changeable factor, varying with gusts of wind, temperature, etc., that it is usually unreliable except for the immediate period during which it is determined, though it does follow temperature in its general trend. The absolute humidity (indicated by the vapor pressure) is the weight of water vapor in a given space. While there is a variation from hour to hour and from day to day in this factor, the change is more gradual and more uniform than that of relative humidity. These fluctuations in actual moisture content of the atmosphere are brought about in varying degrees during the day by evaporation from both land and water surfaces, by transpiration by plant life, and by condensation in the form of rain, dew, or frost. These changes are continuously operating in some manner, evaporation being much more active during the warmer part of the day than during the night, when temperatures are low and the dew point is reached or approximated.

For the control of forest fires it appears that some form of prediction of extreme changes in vapor pressure is needed, and this the Weather Bureau believes it may

⁴ See Palmer, A. H.: Lightning and forest fires, MO. WEATHER REV., August, 1920, 48: 452-453.

be possible to supply, augmenting that now received.⁵ If it were known in advance that the following day would have a very low vapor pressure, the field force of the Forest Service, upon the occurrence of a fire on that day, could dispatch more men to it than would ordinarily be required for a fire in that particular region. On the other hand, with a knowledge of a greatly increasing vapor pressure it would be possible to take a smaller number of men than in the first case, because climatic conditions would be in favor of easy control. Notification in advance of periods of extreme fire hazard would make it possible to augment the Forest Service force to care for the emergency.

Up to the present it has not been possible for the Weather Bureau to predict the local heat type of thunderstorms. The widespread thunderstorms, which accompany low-pressure areas, can very readily be predicted, but the heat type, being entirely local, has so far not been as carefully studied from the forester's standpoint as we should like. A study of the data from Red Bluff for the period 1911 to 1920, inclusive, shows that when the vapor pressure increases rapidly and reaches a point of about 0.380 inch (Hg.) local thunderstorms occur in the high mountain region. When the vapor pressure rises above 0.420 inch rain occurs with these convectional storms. The difference between these two extremes is the danger period during which we have the "dry lightning" storms, when lightning and thunder occur without rain. These are the most dangerous periods for the forest; during such times a large number of fires start, and as no rain falls they have a chance to spread to large size before they can be reached by the field force.

In going over the vapor-pressure data for the period from 1911 to 1920 it was found that in those years and months when the average monthly vapor pressure remained high a very small number of fires occurred, while in those years and months with a relatively low average monthly vapor pressure there were uniformly periods of extreme hazard and many bad fires occurred. Should it be possible by some system of forecasting, such as that of the Scripps Institute [from ocean temperatures]⁶ or by the occurrence of sun spots, to determine in advance what a particular month would be like in the way of fire hazard, our protection system could be put on a much more stable and safer basis than at present.

The whole field of the relation of vapor pressure and evaporation to forest fires offers possibilities which certainly have not been considered to any great degree before. It is planned to study evaporation during the present season on the national forests throughout the State, in order that we may determine the danger points and the possibility of their prediction. If such a study could be made nation-wide, a long step forward would be taken in our knowledge of the physical controls of fire.

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FORECASTING THUNDERSTORMS BY MEANS OF STATIC ELECTRICITY.

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[Naval Air Station, Hampton Roads, Va., Apr. 27, 1921.]

The thunderstorm is one of the greatest obstacles to routine flying during the summer months. At an aviation station it is important, therefore, to know the approximate time of arrival of thunderstorms, their

extent and duration. Unless these things are known, air craft may be caught away from shelter or safe landing place, and may be forced to land where they will be unable to return to their base for hours or days; or, worse still, conditions dangerous to craft and personnel may be encountered. If, on days when thunderstorm conditions prevail, the alternative is taken and flying is suspended in anticipation of thunderstorms which do not arrive for many hours or perhaps not at all, much valuable flying time is lost.

During the summer of 1920, in order to test the value of atmospheric static electricity as an indication of thunderstorms and an aid in forecasting these storms for flying operations, a radiotelegraph receiving set was installed in the aerological office, Naval Air Station, Hampton Roads, Va. The set consisted of a six-step amplifier (type SC 1605B used in Navy seaplanes) with a variable condenser and head phones. The antenna was a Navy standard bidirectional compass coil (type SE 4080). The choice of wave length ranged approximately from 600 to 2,500 meters.

Hourly observations were made each day between 8 a. m. and 4 p. m., with the exception of Saturday afternoon and Sunday. Frequently intermediate observations were made. Data were logged according to the following classification:

- (a) Hour of observation.
- (b) Wave length on which "strays" were most intense.
- (c) Quality of "strays," whether "whip cracks," "grinders," or combination of these.
- (d) Intensity of "strays" whether faint, moderate, strong, or deafening.
- (e) Number of "strays," i. e., whether continuous or intermittent. If intermittent, give number per minute.
- (f) Directional plane to eight points in which "strays" were strongest, i. e., whether they appeared to lie in the north-south plane, the east-west plane, the northwest-southeast plane, or the northeast-southwest plane.
- (g) Change in intensity since last observation, whether increasing or decreasing.
- (h) Amount, azimuth, and size (small, medium, or towering) of any cumulo-nimbus clouds within sight of station.

The following are some averages computed from the total observations:

Average wave length on which best results were obtained, 900 meters.

Average intensity of "strays" on days when no thunderstorms were reported at or near station (based on scale of zero to four), 1.4.

Average intensity of "strays" on days when thunderstorms were reported at or near station, 1.9.

Per cent by which intensity on thunderstorm days exceeded intensity on no thunderstorm days, 36 per cent.

"Strays" seemed to lie most frequently in the northwest-southeast plane (their direction was probably northwest).

The next most frequent plane was southwest-northeast.

From the experience of last summer it is believed that the "static" recorder is a valuable instrument for aerological stations. The above averages minimize rather than magnify the actual usefulness of a "static" indicator in forecasting for aviation. It must be remembered that this attempt was the first of its kind at this station, and that the apparatus used was designed for radiotelegraphy, not for detection of "static" for meteorological purposes. Since under these conditions the "static" log was found of considerable value in forecasting thunderstorms in the vicinity of the air station,

⁵ Beale, Edward Alden: The value of weather forecasts in the problem of protecting forests from fire. *MO. WEATHER REV.*, February, 1914, 42: 111-119.

⁶ See next Review.